An Inaugural Dissertation
on
The Circulation of the Blood
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Circulation of the Blood

The main object of the circulation of the blood is the nutrition of the different tissues of the body by bringing the nutritive fluid in intimate connection with every part of the organism, and thus placing at the disposal of each individual cell the materials for its growth and development. But as every act of life is accompanied by a necessary waste or disintegration of tissue, it becomes an important part of this function to remove from the system these effete materials, by bringing them under the influence of the various secreting organs. It also serves as the media by which oxygen is introduced into, and carbonic acid is eliminated from, the system. Hence it is found that respiration is one of the most important auxillaries of the circulation, by carrying oxygen from the respiratory surface of the lungs too all parts of the body, and by carrying back carbonic acid to be thrown off from the

respiratory surface of the lungs.
The circulatory apparatus consists of four different parts; the Heart; the Arteries; the Capillaries, and the Veins. In each the movement of the blood is peculiar, and will require separate notice.
The Heart is a hollow muscular organ, of an irregularly pyramidal shape; situated obliquely in the left side of the thorax; suspended by its base from the great vessels, and free in the rest of its extent. It is surrounded by a fibrous sheath, the Pericardium the reflection of which closely invests the substance of the heart. Internally the heart is divided into four cavities, two auricles, and two ventricles.
The auricles occupy the upper part, or base of the heart; They are smaller than the ventricles, and their walls are much thinner, and less muscular, and in adult life do not communicate with each other; They receive the blood from the lungs, and the rest of the body, and transmit it to their corresponding ventricles.

The right auricle is a little larger than the left and its walls are thinner, and less muscular. It is connected with the right ventricle, with which it communicates by a large oval aperture, the ostium ventriculi venosum. It receives all the venous blood from the system, through the superior, and inferior venae cavae, and coronary vein, and transmits it to the right ventricle.
The left auricle is smaller than right, and its walls are thicker, and stronger. It opens into the left ventricle, through an orifice called the ostium ventriculi arteriosum. It receives the arterial blood from the four pulmonary veins, and transmits it to the left ventricle.
The ventricles are somewhat larger than the auricles, and form by their union, the apex of of the heart. They are of equal capacity, but the walls of the left are much thicker, and stronger than those of the right. They are separated

from each other by a septum, the septum ventriculorum, which forms their inner walls.
The right ventricle is triangular in shape, and forms the largest part of the anterior portion of the heart. Superiorly the ventricle forms a conical projection, which gives origin to the pulmonary artery. Its walls are thinner than those of the left ventricle. The thickest part of the walls being at the base, and gradually become thinner towards the apex. Internally the right ventricles presents for examination two orifices, and two set of valves. The auriculo ventricular orifice is situated at the base of the ventricle, and is the means of communication with the auricle. It is of oval shape, and is surrounded by a fibrous ring, to which is attached the tricuspid valve, which guards its opening.
The orifice of the pulmonary artery is situated to the left side of the auriculo ventricular opening.

It is circular in form and is guarded by the sigmoid valves.

The tricuspid valve consists of three triangular curtains, which when not in operation, lie within the ventricle. They are attached by their bases to the auriculo ventricular orifice, and by their sides with one another in such a manner as to close the orifice during the contraction of the heart. Their free margins are attached to the walls of the ventricle by numerous fine, delicate, tendinous cords, the chordae tendinae. These segments are depressed to allow the blood to flow from the auricle into the ventricle, and are closed to prevent its reflux into the auricle.

The sigmoid valves, three in number, guard the orifice of the pulmonary artery. They consist of three semicircular foldes of the lining membrane, strengthened by fibrous tissue. They are attached to the walls of the artery at its junction with the ventricle; their free borders being

directed upwards along the course of the artery during the passage of the blood from the ventricle into the artery, but close to prevent its reflux into the ventricle.

The left ventricle is situated at the posterior, and left part of the heart. It is conical in shape, and its parieties are much stronger, and thicker than those of the right. Its walls are thickest at the middle, and gradually diminish in thickness towards the base, and also towards the apex which is the thinnest part.

It also has two orifices, similar to those of the right ventricle, and two sets of valves, the mitral, and sigmoid.

The auriculo ventricular orifice is somewhat smaller than the corresponding one on the right side. It is surrounded by a fibrous ring, to which is attached the mitral valve.

The aortic orifice is situated to the right side, and in front of the auriculo ventricular opening.

Its orifice is guarded by the sigmoid valves.
The mitral valve consists of two segments, formed by the duplicature of the lining membrane of the heart. They are triangular in shape; and are attached by their bases to the margin of the auriculo ventricular orifice in a similar manner to the tricuspid. They are however larger, thicker, and stronger than the tricuspid. They are attached to the walls of the ventricle by the chordae tendinae which are thick, and strong.
It admits the blood from the auricle into the ventricle, but closes to prevent its reflux into the auricle
The sigmoids of the aorta are larger, thicker, and stronger than those of the pulmonary artery. They are attached by their convex borders to the walls of the artery at its junction with the ventricle. They open to allow the passage of the blood from the ventricle into the aorta, and close to prevent its reflux into the ventricle.

The cavities of the heart are lined by a serous membrane, which assists in forming the valves. It is continuous with the inner coat of the veins in the right side of the heart, and with that of the arteries in the left.

The course of the blood through the cardiac cavities is as follows: The blood flows into the right auricle from the two venae cavae and the coronary vein; a portion of it at the same time enters the ventricle. When the auricle becomes distended with blood it immediately contracts, and forces its contents into the right ventricle through the auriculo ventricular orifice. The ventricle thus filled with blood contracts, and the blood at the same time getting behind the chordae tendinae closes the tricuspid valve, and prevents its reflux into the auricle. It then passes through the pulmonary orifice into the pulmonary artery, its reflux being prevented by the closure of the sigmoid valves. From the pulmonary artery the blood passes into the substance of the

lungs and is returned to the left auricle by the pulmonary veins. The left auricle transmits it to the left ventricle; which contracts and forces it into the aorta, the mitral and sigmoid valves preventing the reflux of the blood in the same manner as the valves of the right side.

The contraction of the auricles, and ventricles follow one another in rapid succession, The systole of the auricles, corresponding to the diastole of the ventricles, and the systole of the ventricles to the diastole. Each contraction being called a pulsation.

The arteries are a series of branching tubules, which have their origin in the great aorta, and pulmonary artery, and convey the blood to every part of the system. They terminate by numerous radical branches, in the capillary plexus.

The arteries are highly elastic, and are composed of three different tunic - the internal, middle, and external.

The inner coat consists of a fine, delicate serous membrane, which is continuous with the endocardium of the heart.
The middle coat is composed of muscular fibers and elastic tissue disposed chiefly in the transverse direction. It is exceedingly thick in the large arteries, and diminishes in thickness as the arteries become smaller, and finally disappears. In the small arteries the middle coat is purely muscular. In the arteries of medium size, this coat increases in thickness with the size of the vessel; its muscular layers are intermixed with numerous fine elastic fibers. In the larg arteries the elastic tissue predominates, and formes three fourth of its thickness.
The external coat is composed of connective tissue and elastic fibers. It is very thin in the large arteries, but in those of medium size, and in the smaller arteries it is of equal thickness with the middle coat. It gives mechanical support to the other tunics, and formes its connections with other parts.

The united area of all the branches of an artery considerably exceed that of the trunk from which they are given off, hence it is found that the blood moves with greater rapidity in the large vessels than in the smaller, and this proportion increases with the distance from the heart.

The pulmonary artery is similar in structure to the aorta. It arises from the right ventricle of the heart, and conveys the venous blood to every part of the lungs, where it terminates in the capillary blood vessels which surround the air cells of the lungs.

The arterial system is thus seen to consist of vast number of tubular canals, which divide and subdivide from within outwards by the successive branching of its vessels, which communicate with the aorta, and heart on one hand, and with the capillary plexus on the other; the vessels at all times being filled with blood.

At every contraction of the ventricles a considerable quantity of blood is forced into the arteries, which,

meeting with resistance from the blood already in the arteries, will distend their walls to a considerable extent. When the heart relaxes its force, the sigmoid valves immediately close, and prevent the reflux of the blood into its cavities. At the same time the elastic walls of the arteries react upon their contents, and force the blood forward into the arteries; the wave of blood thus produced distends the walls of the vessels at every step; and is followed by the contraction of the artery, which drives the blood onwards into the capillaries.

In this manner a wave like motion of the blood is produced, which extends through the entire arterial system, causing the phenomenon known as the arterial pulse.

The elastic walls of the arteries also tend to convert the interrupted current of blood into a continuous and even flow, and when it reaches the arterial capillaries, the intermittent character has entirely disappeared, and it flows into the capillaries in a uniform and continuous current.

The capillary blood vessels, are a fine network of inosculating tubules which permeate the substance of all the vascular organs, and bring the blood in intimate connection with all the tissues of the body. They are situated intermediate between the arteries and veins, with which they are continuous. The capillaries of any particular organ are of uniform diameter, and inosculate with one another in such a manner as to form a plexus, which enclose within their meshes the substance of the organ.
It is during the capillary circulation that the blood serves for the nutrition of the different tissues of the body; every individual cell selecting the materials necessary for its growth and renovation.
It is here also that the blood becomes charged with carbonic acid, and other products of decay. The blood thus impoverished is no longer capable of sustaining the nutrition of the part, and is replaced by another portion which is destined to undergo similar changes and in like manner

to be replaced by another and so on. This process is known by the name of capillary attraction and is regulated by the same principles as those which govern the circulation of the sap in vegetables, and is as follows: The different tissues of the body have an affinity, or attraction for certain materials in the circulating fluid; these material are absorbed and changed in their properties, are converted into tissue; and the circulating fluid having given up those materials, has no longer the same affinity for these parts which it had before, and is driven out by another portion which has a superior affinity. Thus the blood in the arterial capillaries having just been charged with oxygen in the lungs, has a stronger affinity for all the tissues through which it circulates than the blood already in the capillaries which has lost its oxygen, and has become charged with carbonic acid, and is consequently driven by it into the veins; the rapidity of its movement,

depending upon the activity of the functional changes going on in the part.
This priciple is more clearly exemplified in the lower animals, which have no central or contractile organ to propell the blood through their vessels. In the entozoa, and acalephae the vessels take up the nutriment directly from the digestive cavity upon the walls of which they ramify. They then unite to form trunks, which convey the nutriment to every part; these trunks afterwards subdivide into smaller or capillary branches, some of which go to the surface are subservient to aeration; the fluid is then collected by other branches, which convey it back to the place from which it started.
The movement of the circulating fluid through their vessels, evidently depending upon the varying affinities existing between the circulating fluid, and the parts throug which it passes.

In *fishes* the heart belongs exclusively to the respiratory system, the blood having to pass through two and a portion of it through three sets of capillaries before it again reaches the heart.

In *the portal circulation* of *man* we see something similar. The blood which passes through the capillaries of the intestines is collected by the *vena portae* which transmits it to the liver: in the substance of which this vessel ramifies; it is then collected by the hepatic vein and emptied into the vena cava.

These examples are sufficient to prove that the capillaries possess a power of controlling the circulation in them, independent of any *vis a tergo* derived from the heart and arteries.

The veins are a series of converging vessels, which have their origin in the capillary plexus, by numerous radical vessels which unite in forming larger trunks, which convey the blood back again to the heart. They are much more numerous than

the arteries, and their capacity is greater.
They are composed of three coats; the internal, middle, and external.
The inner coat, consists of a delicate serous membrane. It is continuous with the endocardium of the right heart, and through the medium of the capillaries, with the inner coat of the arteries.
The middle coat, differs from that of the arteries in containing less muscular and elastic fibers, and more connective tissue. In the smallest veins, it consists of a thin layer of connective tissue, arranged in a longitudinal manner along the vessel. In those of a little larger size, a layer of muscular fibers is added, the cells of which are disposed transversely. In the larger, and medium sized veins, it consists of a thick inner layer of connective tissue with elastic fibers, and in some veins, a layer of transverse muscular fibers; and an outer layer of longitudinal elastic fibers alternating with layers of muscular fibers and connective tissue, and res-

embling somewhat in structure, the middle coat of the arteries.

<u>The external coat</u> is generally the thickest of the three, and increases in thickness with the size of the vessel. In the smallest arteries it consists of a thick layer of connective tissue. In those of medium size, it is much thicker than the middle coat and is composed of elastic fibers and connective tissue arranged longitudinally. In the larger veins it is from two to five times thicker than the middle coat and contains a large number of muscular fibers longitudinally arranged.

The veins are distinguished from the arteries, by the thinness of their walls, and the absence of pulsation, and also by the dark color of their contained blood, and by the flaccidity of their walls which when empty collapse.

They are further more distinguished, throughout the extremities, neck and external part of the body, by being furnished with numerous valves, which are formed by the reduplication of the

inner and middle coats. They are semilunar in shape and are attached to the walls of the veins by their convex borders; their concave borders are free, and directed in the course of the venous current. Most always there are two of these valves placed opposite each other, sometimes as many as three occur, and sometimes only one. They lie in apposition with the walls of the veins, during the normal movement of the blood, but if any reflux takes place, the blood getting behind the valves depress them, and their free margins coming to gather arrest the backward tendency of the blood.

The principal cause of the circulation of the blood in the veins, is the force developed in the capillaries; which continually fills the venous branches with the deoxygenized blood; and when once in the veins the blood is prevented from returning into the capillaries by the valves; and is consequently driven onwards towards the heart by the steady accumulation from behind

The veins which lie among the voluntary muscles are more or less compressed at every contraction, and the blood which is thus driven out by the pressure exerted upon them, cannot regurgitate towards the capillaries, owing to the presence of the valves which arrest its progress in that direction, and it will therefore be driven onwards towards the heart. During the subsequent relaxation of the muscles, the blood from behind rushes in to fill the partial vacuum thus formed. The voluntary muscles being in a state of activity in every positions of the body, will consequently compress some of the veins at every motion, and the force thus exerted must necessarily be an efficient one in producing the venous circulation.

The expansion of the thoracic walls, and descent of the diaphragm during every inspiration, will tend to draw the blood from the large veins into the cavity of the chest, and thereby favor the motion of the blood towards the heart. The blood having in this manner completed the

great circuit of the systemic circulation, is again received into the right cavity of the heart, to be sent through the lesser or pulmonic circulation; where other important changes take place, and other forces combine to return it again to the heart. In the capillaries of the lungs the venous blood is brought in intimate connection with the atmospheric air, in the air cells of the lungs, whereby a mutual exchange of gases takes place. The carbonic acid with which the blood became charged in passing through the systemic capillaries, is thrown off, and is replaced by the supply of oxygen necessary for the action of the muscular and nervous tissue, as well as for the various chemical changes continually going on in the body. In passing through the lungs the blood undergoes a remarkable change in color. It being changed from the dark brown, or bluish hue of the venous blood to the bright red, or florid color which characterizes

the arterial blood. The change in color is undoubtedly caused by the change which the blood globules undergo in giving the carbonic acid which they hold in solution for a new supply of oxygen.

In the pulmonic capillaries the opposite affinities exist to those in the systemic. The one being complimentary to the other. Here, from the peculiar constitution of the parts, the affinity is for the venous blood; which no longer exists, when it has undergone the various changes before mentioned; and it is consequently driven into the pulmonary veins by the superior attraction exerted upon a new portion of the fluid. From the pulmonary veins the blood flows into the left cavity of the heart, preparatory to its being again distributed to the system.

In corroboration of the truth of the principle that the capillaries possess the power of regulating the circulation of the blood through them, independent of the force derived from the heart and

the arteries. I will add but one more of the many illustration which might be adduced in its favor.
In asphixia the venous blood becomes stagnated in the pulmonic capillaries. This cannot be attributed, to the loss, of the contractile power of the heart, for as yet it is not affected, but to the loss of the capillary power, resulting from the lack of oxygen in the lungs to bring about the changes necessary to produce motion. The circulation in the in the capillaries of the lungs is not at first entirely arrested, on account of the oxygen contained in the air already in the lungs, which is sufficient to partially oxydize a portion of the blood, which will continue to move as long as enough oxygen remains to vary the affinity between two portions of the fluid, but when this becomes exhausted, the stagnation is complete. The venous blood is backed up in the pulmonary artery, and right cavity of the heart, and

in the whole venous system. The arteries are at the same time emptied of their contents by the systemic capillaries, which owing to the supply being cut off from the heart have ceased to act. The violent contractions of the heart are entirely inadequate to force the blood through the pulmonic capillaries, as is shown by the engorged state of the pulmonic artery and right cavity of the heart. Its pulsations grow weaker, and weaker, and finally cease - Even now if atmospheric air be admitted into the lungs, movement will be produced, the blood again becomes rich with oxygen, and flows with avidity into the left cavity of the hear, which begins to contract and sends the blood once more through the system, and in this manner the current is restored. The circulation of the blood is thus seen to depend, not upon the mechanical force of the heart, as was supposed by some Physiologists, but upon the combination of the forces, which act upon it in different parts of the system, thus

the heart by its vigorous contractions forces the blood into the arteries, this force, which is mainly expended in dilating the walls of the arteries, is not however lost, but is taken up by these vessels, which by virtue of their elasticity, and muscular contractility, force it onwards into the capillaries. Here the Chemico-Physiological and dynamic forces combine to return it again to the heart, and in this manner the current is kept up, which gives life to every individual cell; untill the Chemical forces, which during life are subservient to the dynamic; exert their universal sway, and convert the mass, which but a moment before was the tenement for an immortal spirit; to resolve into its primary element— dust.